



Analysis software for land, sea, air, & space

Leap Seconds and Literature

John H. Seago (AGI)

Coordinated Universal Time (UTC)

- **UTC is a broadcast standard for coordinating the standard frequencies and timing signals**
 - per ITU-R Recommendation 460.
- **UTC represents a sequence of *SI* seconds progressing at the same rate as TAI maintained by the BIPM, except UTC epochs are adjusted with *leap seconds* to assure concordance with Universal Time to within ± 0.9 seconds.**
- **Adjustments announced in advance by the IERS**
- **Adjustments necessary because Universal Time is the astronomical basis of civil timekeeping**
 - TAI runs at a different rate than Universal Time

The Cost of Change

- **Cessation of leap seconds discouraged without consensus for more than a decade.**
 - Changes to UTC standard now expected to impact many technical operations.
 - Functional definition largely unchanged since early 1970's
- **Issue contributing to debate is the degree of expense.**
 - Organizations / businesses unmotivated to start financial impact assessments until they must
 - Reliable / official cost-estimation typically expensive to generate and approve
 - Scope of impact

The Cost of Change

- **Labor needed to initially identify and report compulsory modifications**
 - the cost of estimating the cost
 - methodical investigations still needed to prove where no modifications are necessary

- **Next level of expenses for affected systems**
 - development of requirements or specifications
 - planning meetings, regulatory paperwork, *etc.*
 - managerial & regulatory expenses for government systems
 - software and hardware development
 - testing and benchmark development
 - implementation and installation
 - lost personnel productivity or data during system outages

The Cost of Change

- **Personnel need to be re-trained or re-educated**
 - directly related to quality documentation
- **Existing documentation would be invalidated by UTC redefinition.**
 - use of UTC is ubiquitous
 - technical confusion without remedy across technology fields
 - has its own financial repercussions otherwise
- **Surveys of digitized documentation might provide insight into affected technology domains**
- **This paper experiments with internet searches to suggest specialized areas that might warrant further examination**

The Experiment

- (UTC OR GMT OR “universal time”) (“leap second” OR “leap seconds”)
- 2,400 matches declared
- 370 viewable outcomes
- Google Scholar tried
 - Many un-useful outcomes



Top Ranked Outcomes



Computer Network
Time Synchronization:
The Network Time
Protocol



Time: From Earth
Rotation to Atomic
Physics



Satellite Orbits:
Models, Methods, and
Applications



Global Positioning
Systems, Inertial
Navigation, and
Integration



Reference Data for
Engineers: Radio,
Electronics, Computer,
and Communications

More General Search

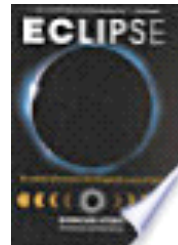
- **More general search tried without requiring “UTC” or “GMT” or “universal time”**
 - Declared more than twice as many matches (5,700) but about the same viewable returns.
 - Less-technical books ranked higher
 - Not as useful



Time: From Earth Rotation to Atomic Physics



Computer Network Time Synchronization: The Network Time Protocol



Eclipse: The Celestial Phenomenon That Changed the Course of History



The Why? Files: The Science Behind The News



Reference Data for Engineers: Radio, Electronics, Computer, and Communications

Caveats

- **Extremely limited discovery**
 - only identified titles written in English
 - searchable documents a fraction of published material
 - scanned titles imperfect, keywords may not be recognized
- **Degree of Consequence**
 - context usually lacking, only surrounding text exposed
 - relevance of UTC definition not always apparent
- **Categorization**
 - process somewhat subjective and likely imperfect
 - Many titles are multi-discipline
 - Multiple editions of same title can may increase some categories

Caveats

- **Despite qualifications, there appears to be some merit for exploring potential areas that could be investigated more deeply**
- **Process also useful for illustrating that documentation revisions may not be a trivial or inexpensive issue if UTC is redefined.**

**Search results informative
but not conclusive**

Categories and Counts

Topical Category	#	Topical Category	#
References (Technical + General)	46	Spacecraft	18
Astronomy	46	Telecommunications	17
Computing	25	Time Transfer	7
Databases (+ IT/IS)	14	Horology	16
Software	13	Science (general interest)	16
Metrology	28	Physics, Science, Math	12
Almanacs, Atlases, and Yearbooks	25	Applied engineering	8
Navigation and Surveying	22	Economics	4
GNSS	19	Electronics	4
Earth science	18	General Interest	11
		<i>Total</i>	<i>369</i>

Word Cloud



Incorrect Nomenclature

Searched Criterion	Declared Matches	Displayed Results
<i>Coordinated Universal Time</i>	9,160	426
Universal Coordinated Time	2,440	446
Universal <i>Coordinate</i> Time	65	65
<i>Coordinate</i> Universal Time	24	24
Coordinated Time Universal	5	5

Categorization of Study Documents

- **Categorizations also applied to collection of ITU-R WP7A and SRG study documents by the ITU-R for supporting redefinition of UTC for comparison**
 - Drafting group documented & summarize ten years' materials
 - developed a “final” report (not publicly released)
 - believed that collected documents “offered a full and comprehensive perspective of the overall [study] effort”
 - “not necessarily a complete compilation”
 - 26 contributed documents plus 17 reports and statements generated within the ITU-R.
- **Because originals not publicly available, classifications loosely assigned according the area of expertise of their originators.**

Categorization of Study Documents

- ***Network time transfer (6)***
 - 3 letters from NIST personnel, report from Time Dissemination Working Group, PTB, report from USNO, report from the Internet Engineering Task Force
- ***Metrology (2)***
 - letter from BEV, Austria, letter from Time Section ROA, Spain
- ***Astronomy (5)***
 - 2 reports from AAS, 2 reports from the IAU, and a communication from RAS.
- ***Navigation and Surveying (2)***
 - letter from Ephemeris Section of the ROA, Spain, communication from the RIN

Categorization of Study Documents

- ***GNSS (3)***

- letter from the Galileo Project Office, ESA, 2 service bulletins from SAAB and ACR Electronics re: GPS receiver reboot

- ***Earth Science (1)***

- letter from International VLBI Service

- ***Spacecraft (5)***

- survey report from CNES and Paris Observatory, letter from EUMETSAT, letter from JSAT Corp., 2 conference papers from me

- ***Applied Engineering (1)***

- Report of the International Union of Radio Science (URSI) Commission J Working Group on the Leap Second (2000).

Categorization of Study Documents

- ***Horology (1)***
 - journal article
- ***Telecom (17)***
 - ITU-R reports and statements submitted by member administrations and organizations.

Summary

Topical Category	#	Topical Category	#
Astronomy	5	Spacecraft	5
Metrology	2	Time Transfer	6
Navigation and Surveying	2	Horology	1
GNSS	3	Applied engineering	1
Earth science (+ IUGG)	1	Telecom (ITU-R)	17
		<i>Total</i>	<i>43</i>

Word Cloud

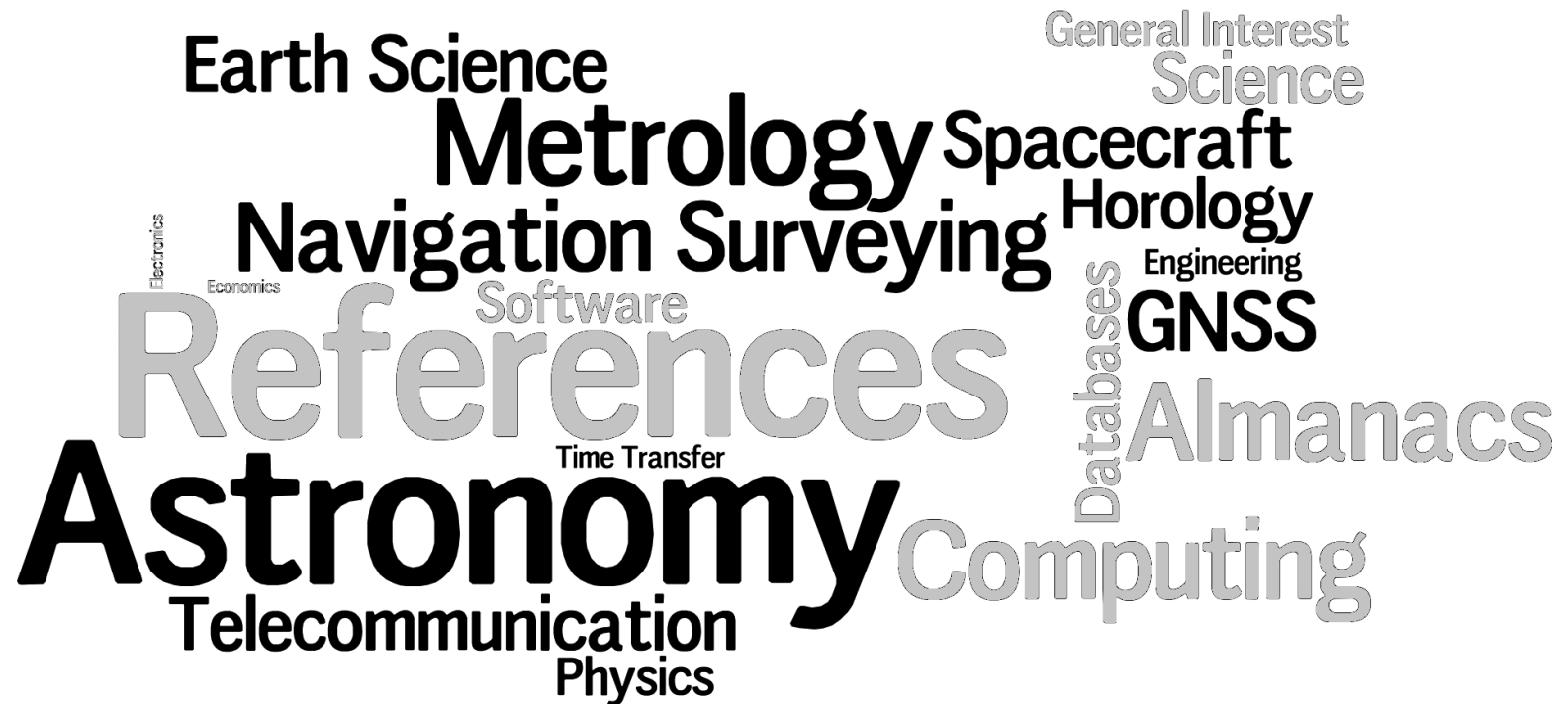
Time Transfer
Earth Science
Metrology
Telecommunication
Horology
Navigation Survey
Astronomy
GNSS
Engineering
Spacecraft

Word Cloud (contributed docs only)



Astronomy
Earth Science
Time Transfer
Engineering
Spacecraft GNSS
Horology
Navigation Survey
Metrology

Word Cloud (internet book search)



Conclusions

- **Information technology allows**
 - technical documentation to become easier to store and access
 - inaccurate or outdated information can also be easily circulated, widely exposed, and persist.
- **Creation of good technical documentation labor intensive, expense often deferred**
 - risk of technical confusion not negligible
- **Documentation changes will affect domains otherwise unaffected by UTC redefinition;**
 - presumed to be very far reaching
- **If UTC is redefined, the identification of affected technical areas will be tricky.**

Conclusions

- **This paper proposes internet search technology to help identify various technology domains that dependent on the definition of UTC**
 - investigations might explore sensitivities to proposed changes
- **Results so far reinforce perception that astronomy and computing could be significantly affected by UTC redefinition**
- **Significant amount of general reference materials would be need updating;**
 - encyclopedias, dictionaries, and almanacs

Conclusions

- **Unclear how study groups have considered certain domains thus far**
 - computing
 - software development
 - Programming
 - Databases
 - applied engineering
- **Added study in these areas might be especially beneficial.**



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